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(54) **LIGHT EMITTING DEVICE**

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(30) **Foreign Application Priority Data**

Dec. 7, 2012 (TW) .... 101146337 A

(51) **Int. Cl.**

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H01L 29/201	(2006.01)
H01L 33/00	(2010.01)
H01L 33/42	(2010.01)
H01L 33/38	(2010.01)
H01L 33/44	(2010.01)

(52) **U.S. Cl.**

CPC ***H01L 33/42*** (2013.01); ***H01L 33/38*** (2013.01); ***H01L 33/44*** (2013.01); *H01L 2933/0025* (2013.01)

(58) **Field of Classification Search**

CPC . H01L 2933/0025; H01L 33/38; H01L 33/42; H01L 33/44

USPC 257/99; 438/26

See application file for complete search history.

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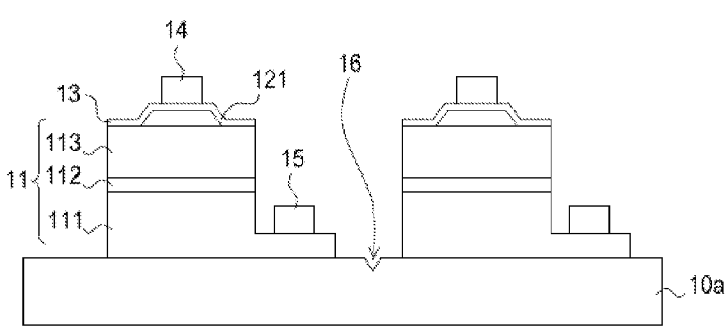
(57) **ABSTRACT**

A light-emitting device is disclosed, comprising a substrate; a light-emitting structure on the substrate comprising a first region and a second region; a barrier layer on the first region having a bottom surface and a sidewall, wherein an angle between the sidewall and the bottom surface is between 10°70°; and a transparent conductive layer formed on the light-emitting structure and the barrier layer; wherein a difference between a thickness of the transparent conductive layer at the sidewall on the barrier layer and a thickness of the transparent conductive layer on the second region of the light-emitting structure forms a ratio not larger than 10 %.

16 Claims, 9 Drawing Sheets



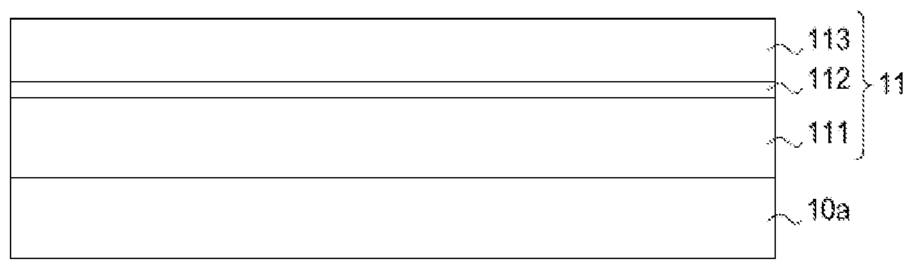


FIG.1A

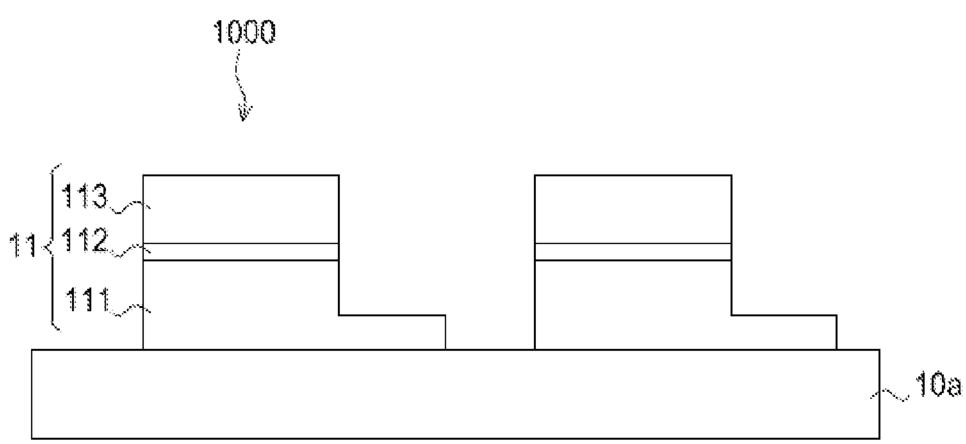


FIG.1B

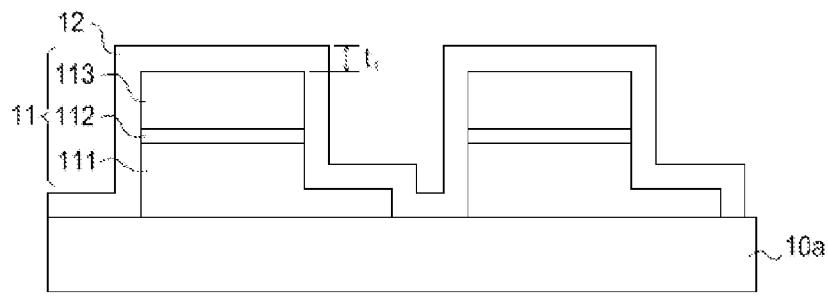


FIG.1C

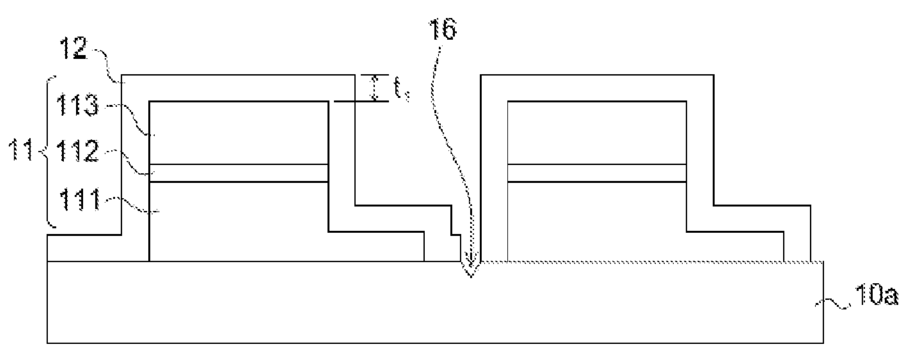


FIG.1D

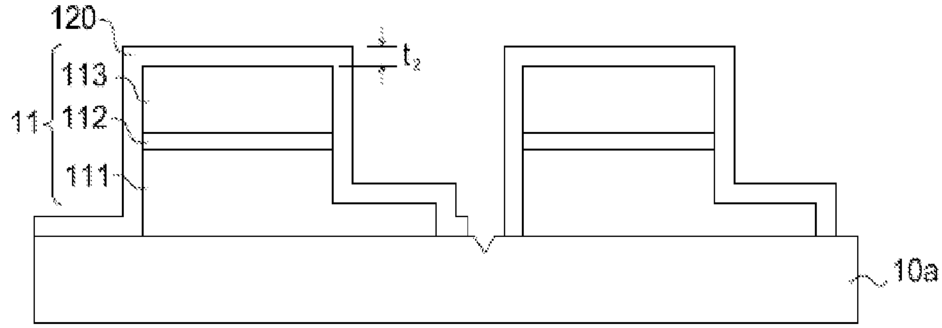


FIG.1E

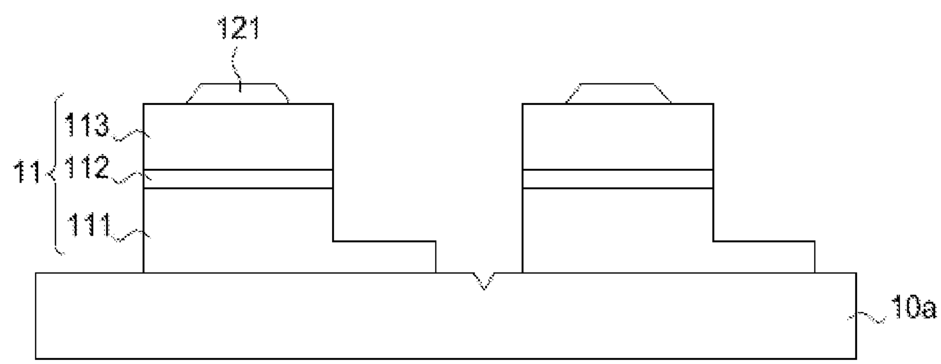


FIG.1F

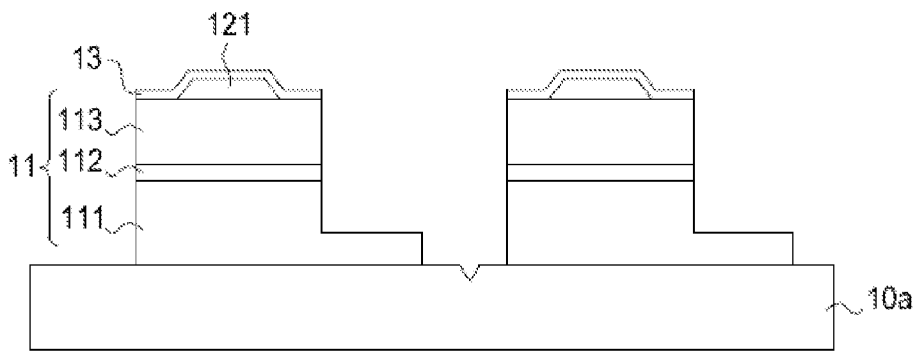


FIG.1G

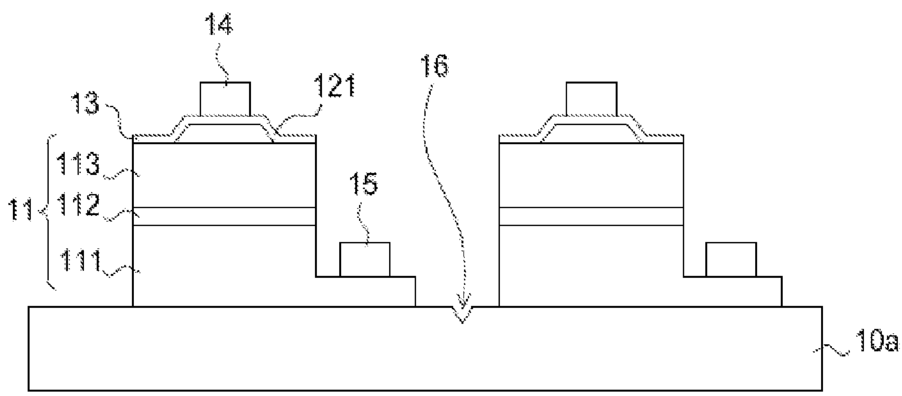


FIG.1H

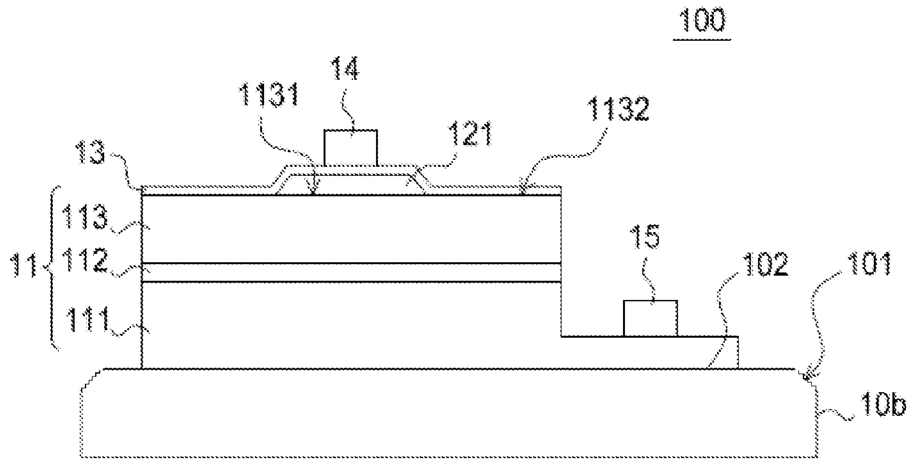

100
14
1131
121
1132
13
113
11
112
111
15
102
101
10b

FIG.2A

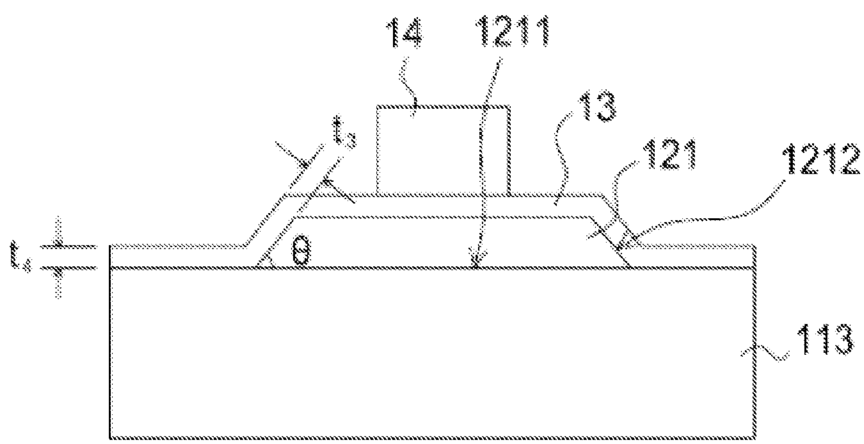

14
1211
13
121
1212
t_3
t_4
θ
113

FIG.2B

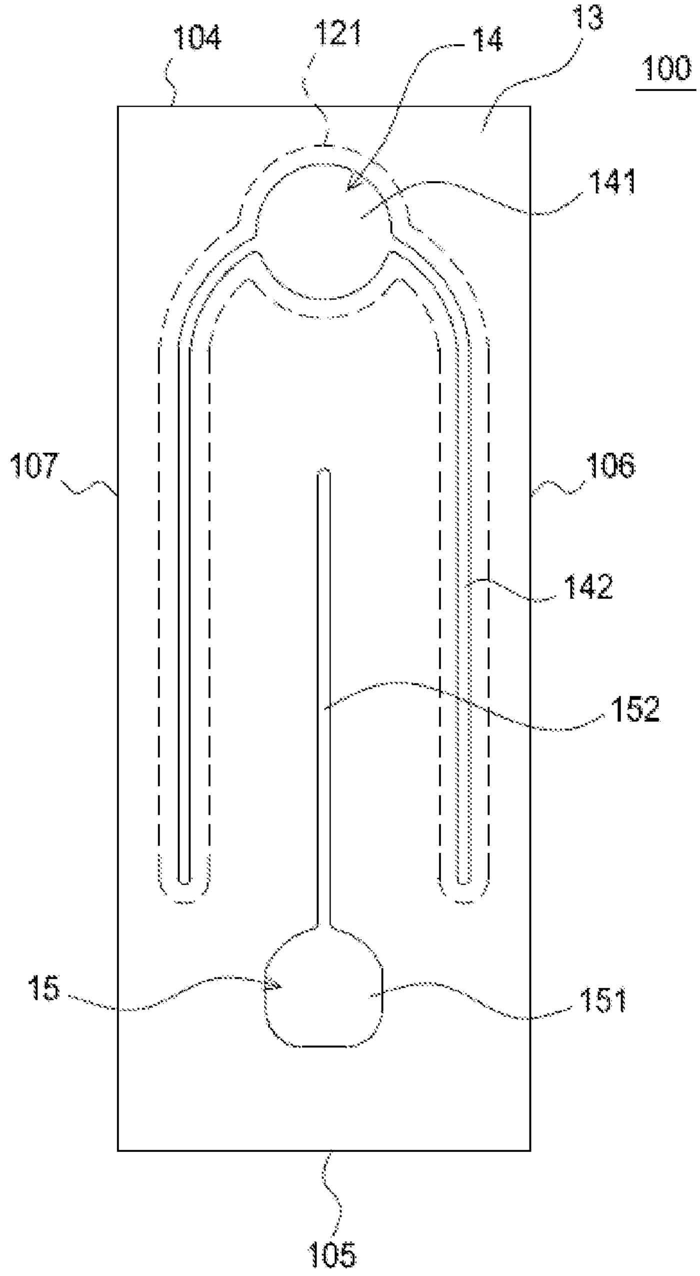


FIG.3A

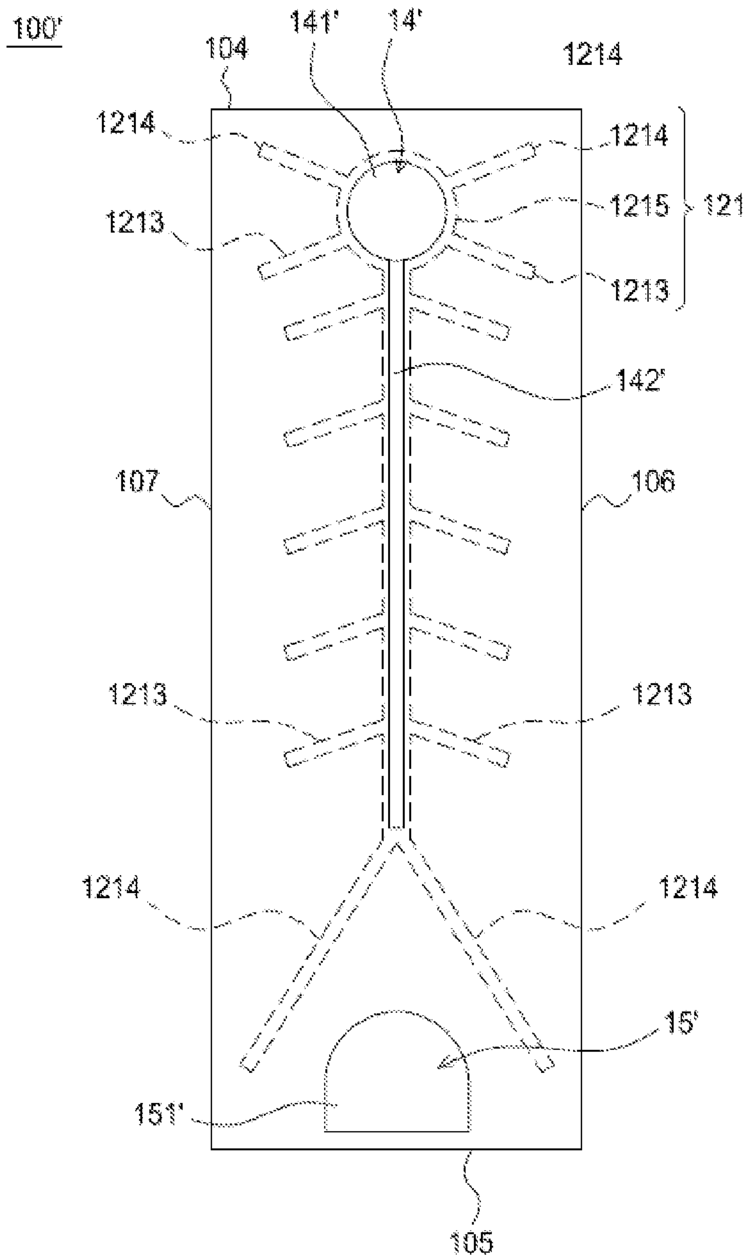

100'
104
141'
14'
1214
1214
1214
1213
1215
121
1213
142'
107
106
1213
1213
1214
1214
15'
151'
105

FIG.3B

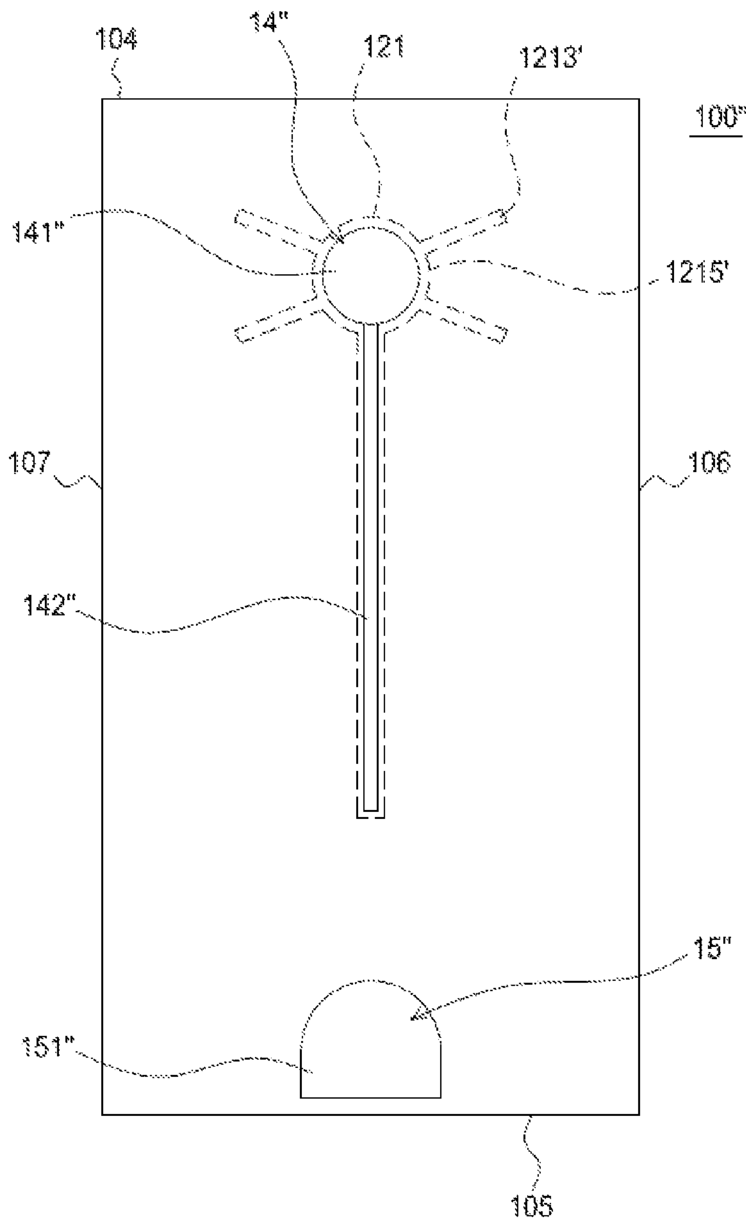


FIG.3C

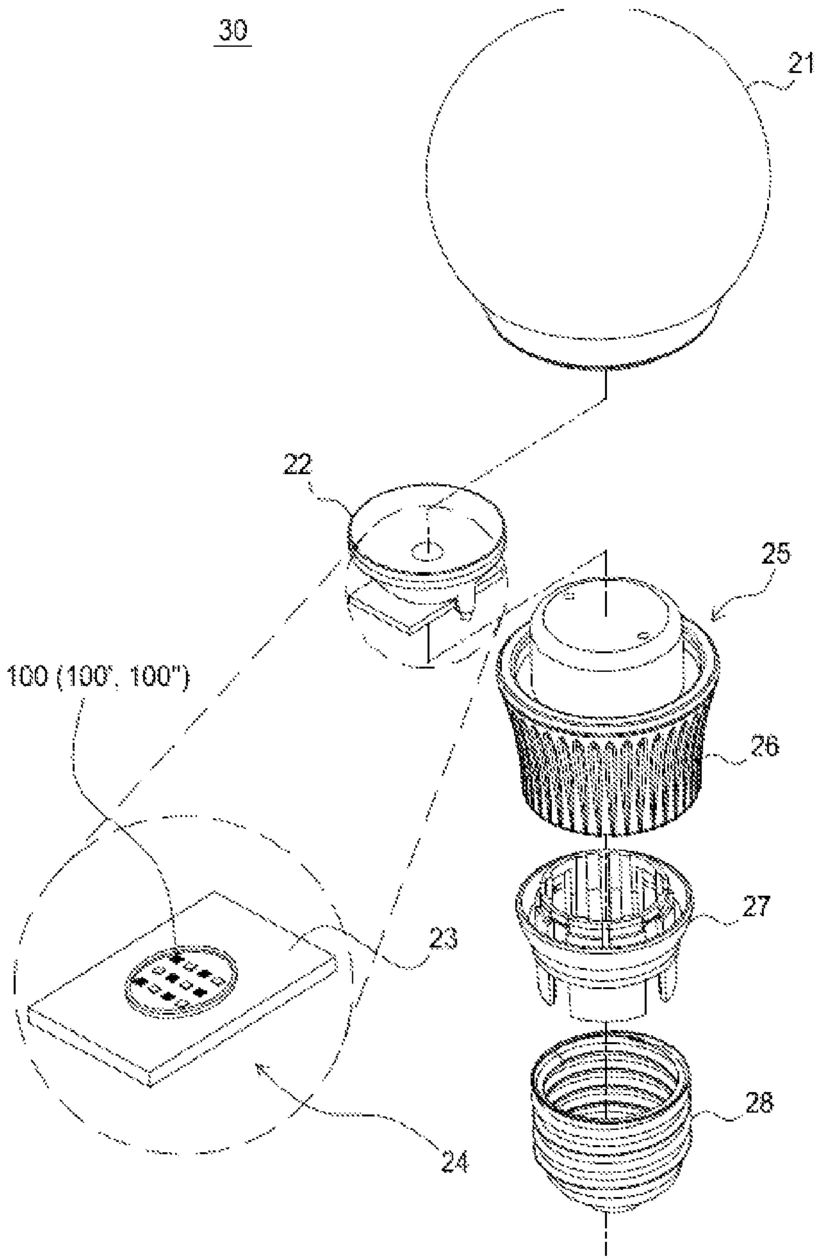


FIG. 4

LIGHT EMITTING DEVICE

BACKGROUND

1. Related Application

This application claims priority from previously filed Taiwan Patent Application No.101146337 filed on Dec. 7, 2012, entitled as "METHOD OF MAKING A LIGHT EMITTING DEVICE AND LIGHT EMITTING DEVIVE MADE THEREOF", and the entire contents of which are hereby incorporated by reference herein in its entirety.

2. Technical Field

The present disclosure relates to a method of making a light-emitting device and in particular to a method of etching a protective layer.

3. Description of the Related Art

The light-emitting diodes (LEDs) of the solid-state lighting elements have the characteristics of the low power consumption, low heat generation, long operational life, shockproof, small volume, quick response and good opto-electrical property like light emission with a stable wavelength so the LEDs have been widely used in household appliances, indicator light of instruments, and opto-electrical products, etc.

Generally speaking, the method of making a light-emitting diode comprises many lithography processes and each of the processes comprises complicated steps. How to reduce the steps of processes and decrease the cost is an important issue.

Besides, light-emitting diodes can be further combined with a sub-mount to form a light emitting device, such as a bulb. The light-emitting device comprises a sub-mount with circuit; a solder on the sub-mount fixing the light-emitting diode on the sub-mount and electrically connecting the base of the light-emitting diode and the circuit of the sub-mount; and an electrical connection structure electrically connecting the electrode pad of the light-emitting diode and the circuit of the sub-mount; wherein the above sub-mount can be a lead frame or a large size mounting substrate for designing circuit of the light-emitting device and improving its heat dissipation.

SUMMARY OF THE DISCLOSURE

A method of manufacturing a light-emitting device comprises: forming a light-emitting structure on a substrate, the light-emitting structure having an active layer; forming a protective layer on the light-emitting structure, the protective layer having a first thickness; etching the protective layer such that the protective layer has a second thickness less than the first thickness; and patterning the protective layer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**H show a cross-sectional view of a method of manufacturing a light-emitting device in accordance with an embodiment of the present disclosure.

FIG. **2**A shows a light-emitting device in accordance with an embodiment according to the manufacturing method of the present disclosure.

FIG. **2**B shows a partial enlarged drawing of FIG. **2**A.

FIGS. **3**A-**3**C show top views of light-emitting devices in accordance with embodiments of the present disclosure.

FIG. **4** shows an exploded drawing of a bulb in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The drawings illustrate the embodiments of the application and, together with the description, serve to illustrate the principles of the application. The same name or the same reference number given or appeared in different paragraphs or figures along the specification should has the same or equivalent meanings while it is once defined anywhere of the disclosure. The thickness or the shape of an element in the specification can be expanded or narrowed. It is noted that the elements not drawn or described in the figure can be included in the present application by the skilled person in the art.

FIGS. **1**A-**1**G show figures of a method of manufacturing a light-emitting device **100** in accordance with an embodiment of the present disclosure.

As shown in FIG. **1**A, a substrate **10*a*** is provided and a light-emitting structure **11** is formed on the substrate **10*a***. In this embodiment, the substrate **10*a*** is a sapphire wafer substrate. The light-emitting structure **11** sequentially comprises a first type semiconductor layer **111**, an active layer **112**, and a second semiconductor layer **113** on the substrate. The first type semiconductor layer **111** and the second semiconductor layer **113** can be a cladding layer or a confinement layer separately provides an electron and a hole to be combined with each other in the active layer **112** and emits a light. As shown in FIG.1B, etching the active layer **112** and the second type semiconductor layer **113** to from a plurality of light-emitting structures **1000**. A plurality of the light-emitting structures **1000** are spaced arranged on the substrate **10*a*** and expose a part of the first semiconductor layer **111**. Besides, the light-emitting device **100** is a horizontal type structure but can also be a vertical type structure or other type structure. As shown in FIG. **1**C, a protection layer **12** is formed to cover the first type semiconductor layer **111**, the active layer **112**, the second type semiconductor layer **113** and the substrate **10*a*** . The protective layer **12** has a first thickness t_1 and is configured to protect the light-emitting structure **11** during the following etching process. In this embodiment, the first thickness t_1 is between 3300-10000 Å. As shown in FIG.1D, a laser is applied to cut the substrate **10** to form a trench **16** in the substrate **10**, wherein the cross section of the trench **16** is a triangle. It is noted that byproducts are generated when using a laser to cut the substrate **10**, and an etching step is applied to remove the byproducts. However, the protective layer **12** is also etched while etching the byproducts. Therefore, as shown in FIG. **1**E, the protective layer **120** has a second thickness t_2 between 3000-9700 Åafter etching the byproducts and the second thickness t**2** is less than the first thickness t_1. The difference between the first thickness t_1 and the second thickness t_2 is larger than 300Å. In this embodiment, the method of etching the byproducts and etching the protective layer **12** at the same time comprises using an acidic solution to etch the byproducts and the protective layer **12**. The acidic solution comprises a mixture solution of a phosphoric acid solution and a sulfuric acid solution, wherein a ratio between the sulfuric acid and the phosphoric acid is about 3:1. In another embodiment, the acidic solution is a phosphoric acid solution. As shown in FIG. **1**F, the protective layer **120** is patterned to be a patterned protective layer **121**. In this embodiment, the patterned protective layer **121** is also configured to be a current barrier layer **121**. As shown in FIG. **1**G, a transparent conductive layer **13** is formed on the barrier layer **121** and the second semiconductor layer **113**. As shown in FIG. **1**H, a first electrode **14** is formed on the transparent conductive layer **13** at the position corresponding to the barrier layer **121** and a second electrode **15** is formed on the first type semiconductor layer **111**. The protective layer **121** or the barrier layer **121** is an insulating material and has a transmittance larger than 90%. Besides, the barrier layer **121** has a resistance larger than 10^{14}Ω-cm. The barrier layer **121** comprises silicon oxide (SiO_2), silicon nitride (SiN_x) or titanium dioxide (TiO_2). Then, splitting the light-emitting structure **1000** along the trench **16** to form a plurality of light-emitting devices **100**.

FIG. **2**A shows a light-emitting device **100** based on the method described in FIGS. **1**A-**1**H. FIG. **2**B shows a partial enlarged drawing of FIG. **2**A. The light-emitting structure **11** is formed on the substrate **10***b*. The light-emitting structure **11** sequentially comprises a first type semiconductor layer **111**, an active layer **112**, and a second type semiconductor layer **113**. The second type semiconductor layer **113** comprises a first region **1131** and a second region **1132**. A barrier layer **121** is formed on the first region **1131** and has a lower surface **1211** and a side wall **1212** which is inclined against the lower surface **1211** and an angle (θ) between the sidewall and the bottom surface is between 10°-70°. A transparent conductive layer **13** is formed on the side wall **1212** of the barrier layer **121** and has a third thickness (t_3); the transparent conductive layer **13** is also formed on the second region **1132** of the second semiconductor layer **113** and has a fourth thickness (t_4). Since the angle (θ) between the sidewall **1212** and the lower surface **121** is less than 70°, the transparent conductive layer **13** can cover the side wall **1212** of the barrier layer **121** and the second region **1132** of the second semiconductor layer **113** uniformly. In this embodiment, a difference (t_3-t_4) between the thickness of the transparent conductive layer **13** formed on the sidewall **1212** of the barrier layer **121** and the thickness of the transparent conductive layer **13** formed on the second region **1132** of the second semiconductor layer **113** and the thickness (t_3) of the transparent conductive layer **13** formed on the side wall **1212** of the barrier layer **121** forms a ratio ((t_3-t_4)/t_3) less than 10%. Besides, since a trench **16** of a triangular shape (referring to FIG. **1**D) is formed in the substrate **10***a* when applying a laser, an inclined sidewall **101** of the substrate **10***b* is formed while splitting the light-emitting structures **1000** to form a light-emitting device **100**. The inclined sidewall **101** is inclined against an upper surface **102** of the substrate **10***b* and an angle between the inclined sidewall **101** and the upper surface **102** of the upper surface **102** is larger than 90°. Moreover, an acidic solution is used to remove the byproducts generated by laser cutting after the inclined sidewall **101** is cut by laser so that the inclined sidewall **101** has a rough surface.

FIGS. **3**A-**3**C show top views of light-emitting devices **100**, **100'** and **100"**. The light-emitting device **100**, **100'** or **100"** has a rectangular shape and has a first side **104**, a second side **105**, a third side **106**, and a fourth side **107**. As shown in FIG. **3**A, the light-emitting device **100** has a first electrode **14** near the first side **104** and the first electrode **14** is formed at the position on the transparent conductive layer **13** opposing to the barrier layer **121**. In this embodiment, the first electrode **14** has a shape substantially the same as that of the barrier layer **121**. The first electrode **14** comprises a first electrode pad **141** and a plurality of first extended electrodes **142** extending from the first electrode pad **141**. The area of the barrier layer **121** is larger than the area of the electrode pad **141** and the extended electrode **142**. The light-emitting device **100** further comprises a second electrode **15** near the second side **105** opposing to the first side **104**. The second electrode **15** comprises a second electrode pad **151** and a second extended electrode **152** extending to the first side **104** while a first extended electrode **142** extends from the first electrode pad **141** to the second electrode pad **151** (in a direction toward the second side **105**). Besides, the first electrode pad **141** can also be placed at a corner near the first side **104** and the third side **106**, the second electrode pad **151** can also be placed at a corner near the second side **105** and the fourth side **107**, and the second extended electrode **152** extends toward the first electrode pad **141**. In another embodiment, as shown in FIG. **3**B, the light-emitting device **100'** comprises a first electrode **14'** and a second electrode **15'**. The first electrode **14'** comprises a first electrode pad **141'** and a first extended electrode **142'**. The second electrode **15'** comprises a second electrode pad **151'**. The first extended electrode **142'** extends in a direction from the first electrode pad **141'** to the second electrode pad **151'**. Besides, a barrier layer **121** comprises an electrode region **1215**, a plurality of first extension regions **1213**, and a plurality of second extension regions **1214**. The electrode region **1215** of the barrier layer **121** is formed on the region corresponding to the region of the first electrode **14'** and has a shape substantially the same as the first electrode **14'** and an area larger than that of the first electrode **14'**. The first extension region **1213** extends from the electrode region **1215** (the first electrode pad **141'** and the first extend electrode **142'**) to the side wall (the third side **106** and the fourth side **107**). In this embodiment, four second extension regions **1214** extend forward (in a direction to the first side **104**) and backward (in a direction to the second side **105**) form the electrode region **1215** (the first electrode pad **141'** and the first extend electrode **142'**). The first electrode **14'** is not formed on the first extension region **1213** and the second extension region **1214**.

As shown in FIG. **3**C, in another embodiment, the light-emitting device **100"** comprises a first electrode **14"** and a second electrode **15"**. The first electrode **14"** comprises a first electrode pad **141"** and a first extended electrode **142"**. The second electrode **15"** comprises a second electrode pad **151"**. The first extended electrode **142"** extends in a direction from the first electrode pad **141"** to the second electrode pad **151"**. Besides, a barrier layer **121** comprises an electrode region **1215'** and a plurality of extension regions **1213'**. The electrode region **1215'** of the barrier layer **121** is formed on the region corresponding to that of the first electrode **14"** and has a shape substantially the same as the first electrode **14"** and an area larger than that of the first electrode **14"**. A plurality of extension regions **1213'** extends from the electrode region **1215'** (the first electrode pad **141"** and the first extend electrode **142"**) to four sides (**104**,**105**,**106**, and **107**) at an angle of 45°. The first electrode **14"** is not formed on the extension region **1213'**.

The first type semiconductor layer can be an n-type semiconductor and the second type semiconductor layer can be a p-type semiconductor. The first type semiconductor layer and the second semiconductor layer comprise AlGaAs, AlGaInP, AlInP, InGaP, AlInGaN, InGaN, AlGaN and GaN. Optionally, the first type semiconductor layer can be a p-type semiconductor layer and the second type semiconductor layer can be an n-type semiconductor layer. The active layer comprises AlGaAs, AlGaInP, InGaP, AlInP, AlInGaN, InGaN, AlGaN and GaN. The active layer can be a single heterostructure (SH), a double-side double heterostructure (DDH) or a multi-quantum well (MQW) structure. The substrate comprises GaAs, GaP, Ge, sapphire, glass, diamond, SiC, Si, GaN, and ZnO or other substitution material.

FIG. **4** shows an exploded drawing of a bulb **30** in accordance with an embodiment of the present disclosure. The bulb **30** comprises a cover **21**, a lens **22**, a light emitting module **24**, a substrate **25**, a heat-dissipation element **26**, a connection element **27**, and a circuit element **28**. The light emitting module **24** comprises a carrier **23** and a plurality of light-emitting devices. The light-emitting device can be any of the light-emitting device **100** (**100'** and **100"**) mentioned above. As shown in FIG. **4**, for example, twelve light-emitting devices are placed on the carrier **23** comprising six red light light-emitting devices and six blue light light-emitting devices arranged staggered and electrically connected to each other (in series or in parallel). The blue light light-emitting device comprises a phosphor device formed above to convert the light emitted from the blue light light-emitting device. The light emitted by the blue light light-emitting device and the converted light are mixed to be a white light which is matched with a red light light-emitting device to emit a warm white light having a color temperature between 2400-3000K.

It will be apparent to those having ordinary skill in the art that various modifications and variations can be made to the devices in accordance with the present disclosure without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the present disclosure covers modifications and variations of this disclosure provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A light-emitting device, comprising:

a substrate;

a light-emitting structure on the substrate comprising a first region and a second region;

a barrier layer on the first region having a bottom surface and a sidewall; and

a transparent conductive layer formed on the light-emitting structure and the barrier layer;

wherein an angle between the sidewall and the bottom surface is between 10°-70°;

wherein the transparent conductive layer is formed between the sidewall of the barrier layer and the second region of the light-emitting structure, wherein a difference between a thickness of the transparent conductive layer at the sidewall on the barrier layer and a thickness of the transparent conductive layer on the second region of the light-emitting structure forms a ratio not larger than 10%.

2. The device of claim **1**, wherein a thickness of the barrier layer is larger than 3000 angstroms and less than 9700 angstroms.

3. The device of claim **1**, further comprising a first electrode formed on the transparent conductive layer at a position corresponding to the barrier layer, wherein the first electrode has a shape substantially the same as the barrier layer.

4. The device of claim **3**, wherein the first electrode comprises a first electrode pad and an extended electrode; the light-emitting device further comprises a second electrode which comprises a second electrode pad; and wherein the extended electrode extends from the first electrode pad to the second electrode pad.

5. The device of claim **1**, further comprising

an electrode formed on the transparent conductive layer wherein the electrode comprises an electrode pad and an extended electrode, the light-emitting structure comprises four sides, and the barrier layer comprises an electrode region on a position corresponding to the electrode and an extension region extending to the four sides from the electrode region.

6. The device of claim **1**, wherein the barrier layer comprises an insulation material having a resistance larger than 10^{14} Ω-cm.

7. The device of claim **1**, wherein the substrate comprises an inclined sidewall.

8. The device of claim **7**, wherein the inclined sidewall comprises a rough surface.

9. A light-emitting device, comprising:

a substrate;

a light-emitting structure on the substrate comprising a first region and a second region;

a barrier layer on the first region having a bottom surface and a sidewall, wherein an angle between the sidewall and the bottom surface is between 10°-70°; and

a transparent conductive layer formed on the light-emitting structure and the barrier layer;

wherein a difference between a thickness of the transparent conductive layer at the sidewall on the barrier layer and a thickness of the transparent conductive layer on the second region of the light-emitting structure forms a ratio not larger than 10%.

10. The device of claim **9**, wherein a thickness of the barrier layer is larger than 3000 angstroms and less than 9700 angstroms.

11. The device of claim **9**, further comprising a first electrode formed on the transparent conductive layer at a position corresponding to the barrier layer, wherein the first electrode has a shape substantially the same as the barrier layer.

12. The device of claim **11**, wherein the first electrode comprises a first electrode pad and an extended electrode; the light-emitting device further comprises a second electrode which comprises a second electrode pad; and wherein the extended electrode extends from the first electrode pad to the second electrode pad.

13. The device of claim **9**, further comprising

an electrode formed on the transparent conductive layer wherein the electrode comprises an electrode pad and an extended electrode, the light-emitting structure comprises four sides, and the barrier layer comprises an electrode region on a position corresponding to the electrode and an extension region extending to the four sides from the electrode region.

14. The device of claim **9**, wherein the barrier layer comprises an insulation material having a resistance larger than 10^{14} Ω-cm.

15. The device of claim **9**, wherein the substrate comprises an inclined sidewall.

16. The device of claim **15**, wherein the inclined sidewall comprises a rough surface.

* * * * *